DOSIMETRIC PROPERTIES OF GERMANIUM DOPED CALCIUM BORATE GLASS FOR USE AS PHOTON DOSIMETER

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I specially dedicate this work

To my dear parents Tengku Kamarul Bahri bin
Tengku Kamarul Zaman Azizan binti Mohd Ismail

To my family's member
Whose love, kindness, patience and prayer have brought me this far

To my supervisors, friends And Everybody
that have contributed For their love,
understanding and support

Thank you very much!!!

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aAllah'Allahblessusallwithsuccessinboththisworld and intheHereafter,Insha

Jazakum Allahu khairan, and peace to all.

ABSTRACT

Borate glasses have been widely studied due to their features as glass formers and present a very useful material for radiation dosimetry applications. The fundamental properties of germanium doped calcium borate glass; (30 -x)CaO $70B_2O_3$: $xGeO_2$ (x = 0.1, 0.2, 0.3, 0.4 and 0.5 mol%) prepared using melt-quenching method were investigated. The physical properties including the amorphous state, density and molar volume were measured. The structural analyses were carried out using infrared transmission spectra and optical properties were determined from ultraviolet-visible optical spectra. Weight fraction obtained from energy dispersive X-ray spectrometry analysis leads to the determination of the effective atomic number of the sample. The total mass attenuation coefficients at photon energies of 0.662 MeV and 1.25 MeV were also calculated by using WinXCom software. Thermoluminescence properties measurements were performed by irradiating the glasses with ^{60}Co gamma ray, 6 MV and 10 MV photon beam with doses ranging from 0.5 Gy to 4.0 Gy. The amorphous phases of the glass samples were identified from this study. The effective atomic number of glass sample was found to be between 11.70 to 12.52 for GeO_2 concentration of 0.1 to 0.5 mol%. The values are quite close to the effective atomic number of the bone, which is 14. The densities, absorption band, molar volumes, optical band gap and refractive index indicate that GeO_2 acts differently on the glass structure over their compositions. The glow curves were analysed to determine various thermoluminescence characteristics of the glass samples. The glass sample with GeO_2 concentration of 0.1 mol% has the best thermoluminescence characteristics such as linearity, sensitivity, fading and reproducibility. In conclusion, germanium doped calcium borate glass has potential to be considered as thermoluminescence dosimeter.

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ABSTRAK

Kaca borat telah dikaji dengan meluas berikutan cirinya sebagai kaca pembentuk dan menunjukkan bahan yang sangat berguna untuk penggunaan dosimetri sinaran. Ciri asas kaca kalsium borat terdop dengan germanium; (30 x)CaO -70B_2O_3: xGeO_2 (x = 0.1, 0.2, 0.3, 0.4 dan 0.5 mol%) yang telah disediakan menggunakan teknik pelindapan lebur telah dikaji. Ciri fizikal termasuklah fasa amorfus, ketumpatan dan isipadu molar telah diukur. Analisis struktur dikaji menggunakan spektrum penghantaran inframerah dan ciri optik telah ditentukan daripada spektrum optik ultraungu-nampak. Pecahan berat yang diperoleh daripada analisis spektrometer sebaran tenaga sinar-X membolehkan penentuan nombor atom berkesan sampel kaca. Pekali pengecilan jisim keseluruhan pada tenaga foton 0.662 MeV dan 1.25 MeV juga dihitung menggunakan perisian WinXCom. Pengukuran ciri termopendarcahaya dilakukan dengan menyinarkan sampel kaca dengan sinar gama ^{60}Co, alur foton 6MV dan 10 MV pada julat dos antara 0.5 Gy hingga 4.0 Gy. Fasa amorfus bagi semua sampel kaca telah dikenalpasti dalam hasil kajian ini. Nombor atom berkesan sampel kaca yang ditentukan bernilai antara 11.70 hingga

12.52 bagi kepekatan GeO_2 antara 0.1 hingga 0.5 mol%. Nilai ini hampir sama dengan nombor atom berkesan bagi tulang, iaitu 14. Ketumpatan, jalur serapan, isipadu molar, jurang jalur optik dan indeks biasan menunjukkan GeO_2 berfungsi secara berbeza ke atas struktur kaca mengikut komposisi. Lengkung berbara yang diperoleh dianalisis bagi menentukan pelbagai ciri sampel kaca tersebut. Sampel kaca yang mempunyai kepekatan GeO_2 0.1 mol% didapati mempunyai ciri termopendarcahaya seperti kelinearan, kepekaan, kelunturan dan kebolehgunaan semula yang terbaik. Sebagai kesimpulan, kaca kalsium borat terdop dengan germanium mempunyai keupayaan untuk dipertimbangkan sebagai dosmeter termopendarcahaya.

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LIST OF SYMBOLS

Mean thermoluminescence background signal

Standard deviation

Tandatangan : Tarikh :

Nama :

Jawatan (Cop rasmi) :

Tandatanga n : Tarikh :

Nama :

Jawatan (Cop rasmi) :

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CHAPTER 1

INTRODUCTION

1.1 Research background

Thermoluminescence dosimetry is used in many scientific and applied fields such as radiotherapy, radiation protection, industry, clinic, and space and environment research, using many different materials. In general, the basic demands of a thermoluminescence material to be used for dosimetric are low hygroscopicity, large linearity, energy non dependence and high sensitivity for a low dose measurements. After Daniels et al. (1953) first applied the thermoluminescence (TL) phenomenon on dosimetry use, research on thermoluminescence continued in the twenty-first century. Borate compounds are among inorganic materials that have been studied with respect to the TL dosimetry requirements. Borates are extensively studied because of its easy preparation, low cost and high sensitivity compared to other TL materials (Jiang et al., 2009). Since these borate compounds show an effective atomic number close to that of human tissue (Z_{eff} = 7.42), borates become the best choice materials to be used in medical and environmental dosimetry (Rojas et al., 2006). So far, research on thermoluminescence characteristics of borate compounds focuses on lithium borate. Lithium borate compounds are considered due to their low cost, near tissue equivalent absorption coefficient (Z_{eff} =7.3) and easy handling process. Schulman et al. (1965) are the first to be acknowledged for starting the TL studies on lithium borate compounds and then, various TL studies of alkali and alkaline earth tetra borates are continued up to present times especially on magnesium and lithium borate compounds.

1.2 Statement of the problem

A glass system composed from B_2O_3, modified by oxide of CaO and doped with GeO_2 is studied. Germanium makes the sample become glass because it can form a highly cross-linked network of chemical bonds. Calcium oxide is used as the modifier in order to have highly stable and durable phosphor. So far, the studies of thermoluminescence characteristics are concerned on magnesium and lithium borate glass. There is very few work done on the combination of borate, calcium oxide and germanium. Therefore, in this work thermoluminescence properties of germanium doped calcium borate glass subjected to photon irradiation are investigated.

1.3 Objectives of study

The aim of this study is to investigate the fundamental properties of germanium doped calcium borate glass which can be use for thermoluminescence dosimeter. The overall objectives are summarized as follows:

Tandatangan : Tarikh :

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Jawatan (Cop rasmi) :

1.4 Scope of study

In order to achieve the objectives, the following scopes are carried out:

i) Preparations of germanium doped calcium borate glasses using melt quenching technique. ii) Determination vitreosity of germanium doped calcium borate glasses using X-ray diffraction technique. iii) Determination concentration of germanium doped calcium borate glasses using energy dispersive X-ray analysis. iv) Determination density and molar volume of germanium doped calcium borate glasses. v) Determination optical study of germanium doped calcium borate glasses using ultraviolet-visible (UV-Vis) optical spectra. vi) Determination structural information of germanium doped calcium borate glasses using fourier transform infrared (FTIR) transmission spectra.

vii) Determination total mass attenuation coefficients and partial interactions of germanium doped calcium borate glasses at photon energies of 0.662 MeV and 1.25 MeV by using WinXCom software.
viii) Perform glass samples irradiation using gamma radiation using ^{60}Co. ix) Perform glass samples irradiation to 6 MV and 10 MV photon using PRIMUS MLC 3339 linear accelerator (LINAC). x) Determination of TL properties using TLD reader model 4500 Harshaw.

1.5 Significance of study

This study may provide a basis for exploiting TL phenomena of calcium borate doped with germanium. General characteristics consist of linearity, sensitivity, re-use, reproducibility, effective atomic number and fading may provide germanium doped calcium borate glasses to be introduced as a new thermoluminescence dosimeter particularly in environmental dosimeter and radiation therapy application. It is hoped that results from this study will help the development of this new material and will establish germanium doped calcium borate glass a very potential and recommended glassy detector that can be used in many applications.

1.6 Report outline

Chapter 1 is a brief introduction of the study that consists of problem statements, objectives of the study, scope, significance, and finally thesis outline. Literature review is in Chapter 2, which covers glass and thermoluminscence theory, advantages of borate, calcium and germanium. Chapter 3 explains the experimental methods used starting from the glass preparation, physical, structural and optical methods of X-ray diffraction (XRD), density and molar volume measurements, fourier transform infrared (FTIR) spectroscopy as well as ultraviolet-visible (UV-Vis) spectroscopy. Determination of effective atomic number from energy dispersive X-ray (EDX) analysis results and mass attenuation coefficients using WinXCom software also include in this chapter. These measurements are ending up with TL glow curves analysis. Chapter 4 presents and discusses results obtained from germanium doped calcium borate glass systems. Last but not least, Chapter 5 provides the summarization results from this study and gives some recommendations for future study.

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